KNOWLEDGE ACQUISITION FOR AN EXPERT SYSTEM IN THE AIR FORCE CIVIL ENGINEERING OPERATIONS BRANCH

THESIS

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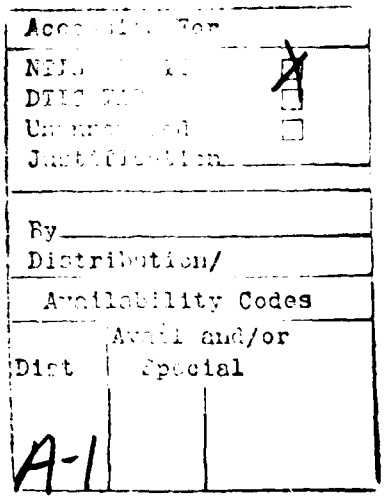

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THESIS

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Abstract

Expert systems are being developed in several industries throughout the world. The key element in these systems is gathering the knowledge. The purpose of this study was to establish procedures for gathering this knowledge in Air Force Civil Engineering. As a test of the procedures, an expert system was created to solve two common semistructured decisions in civil engineering operations. These two decisions involved approving or disapproving a work request, and then determining the appropriate method of accomplishing approved work.

The primary emphasis of the study was on developing and exercising a specific methodology for extracting the knowledge. Several journals and periodicals were reviewed to determine what makes up an expert system and how a knowledge base is developed.

The methodology of knowledge acquisition involved five general steps. The steps included knowledge familiarization, expert selection, interviewing, knowledge representation, and finally automation. Each step is clearly defined in this thesis.

The knowledge base was automated using the expert shell VP-Expert by Paperback Software. The knowledge acquisition steps used in this research and the automated knowledge base are launching platforms for future research involving expert

systems in Air Force Civil Engineering. Recommendations for further research are provided within this thesis.

KNOWLEDGE ACQUISITION FOR AN EXPERT SYSTEM IN THE AIR FORCE CIVIL ENGINEERING OPERATIONS BRANCH

I. Introduction

Future of Computers in Civil Engineering

The advent of inexpensive, yet powerful computer resources has led to their application in several locations. 'Recent breakthroughs in computer technology have made it possible to develop systems which perform many of the functions normally done by experts' (9:1). Expert systems use a heuristic approach to problem solving which is well suited to the semistructured and unstructured decisions made by middle and higher level management (14). The unstructured portion of the decision is primarily based on the manager's experience and background.

Decision Making in Civil Engineering. Many decisions in civil engineering are well defined and follow set procedures. The structured problems are routine in nature and can be easily solved by lower level workers (16:21). When selecting materials for a job, the craftsman will look at the requirements and match those needs with the materials available.

Unstructured or semistructured decisions are not as well defined. They require consideration of many factors and

insight into the problem. An example is deciding whether to hire an employee. Several factors must be considered along, with a great deal of insight to determine if the candidate is capable of accomplishing the required duties. The manager will look at a potential candidate's work history and educational background, along with other factors to decide whether the candidate should be hired.

Expert systems and management attack problems that are less structured and involve data that may be incomplete or uncertain (26:51). Unstructured and semistructured decisions are frequently made by experts with a great deal of past experience (6:22).

The majority of decisions made by the Chief of Operations and Chief of Requirements in CE are semistructured. Eighty percent of the Chief of Requirement's decisions are semistructured, while seventy-four percent of the Chief of Operation's decisions are semistructured (16:70). Appendix A lists the top ten semistructured decisions made by the Chief of Operations and Chief of Requirements as identified by Captain Mastrangeli in his thesis (20:80-83). Captain Mastrangeli determined that the two most common semistructured decisions in the civil engineering operation's branch are:

1. Should a particular work request be approved or disapproved?

2. What is the best method to accomplish identified work; job order, work order, or contract?

This area of work order and job order management was also identified by experienced civil engineers as the most promising area for development of an expert system (13:57-58).

Statement of Problem

Before an expert system can be built, the thought process used by experts in solving the identified decisions must be determined. This is commonly referred to as knowledge acquisition (27:163). The experts' knowledge must be captured and understood.

Research Questions

The following questions must be answered in order to solve the specific problem.

1. What are the steps in knowledge acquisition and how are they performed?

2. Who are the domain experts in the civil engineering field that can supply the knowledge?

3. What is the thought process used by experts when responding to the specific semistructured questions previously identified?

4. Can the experts' responses be put in rules that correspond to the initial steps of building an expert system?

Value of Expert Systems

An expert system programmed to respond to the most frequently occurring semistructured decisions in operations

could help a non-expert arrive at good decisions, reassure the experienced manager, and train the new or inexperienced manager about the decision in question. The expert system will act like the manager's thought process by making inferences, guesses, and asking questions for additional information (27:7).

Reasons for Expert Systems. There are three primary reasons for building expert systems (15:10).

1. Replication of expertise -- the knowledge of a human expert can be consulted even when the expert is not available.

2. Union of expertise -- the expertise of several different specialists can be brought together in an expert system.

3. Documentation -- the best knowledge available for dealing with a particular problem can be recorded and thus used for consultations and for training.

Examples. Numerous successful examples of expert systems exist today. Since the days of World War II, geologists were convinced that a rich molybdenum deposit lay buried under Mount Tolman in the state of Washington (19:43). For years only small piles of molybdenum were found, until the data were fed into an expert system called PROSPECTOR. PROSPECTOR gave geologists directions to where they found a $100 million molybdenum deposit (19:43).

AT&T has a successful expert system that has been running for the past five years.

> Developed by AT&T, Automated Cable Expertise (ACE) is an expert system that contains distilled knowledge in the form of if-then rules. This knowledge comes from the people who know cables best: the telephone company cable maintenance experts. This expert system has been working since 1982 to help the cable maintenance force of the Southwestern Bell Telephone Company [3:206].

Expert systems may also be a common tool seen in the maintenance field. According to Mr Edward Fink, HQ/AFLC, we may see shop personnel carrying portable expert systems to the job site to help diagnose equipment failures (8).

Expert System Limitations. Like most new technologies, expert systems have their limitations. Keim explains some of the user-friendly interfaces are difficult to understand. Expert systems sometimes have problems interfacing with existing data bases. They typically do not follow the actual advice giving role of the human expert, but are more geared on producing solutions. Users are sometimes annoyed by a system that constantly gives advice (15:13).

Other troubles occur if expert system technology is applied to the wrong type of decision. There are seven general types of decisions which are unsuitable for expert system application (15:10):

1. Decisions which have very few rules (e.g. less than 10). These decisions are handled quite well by humans.

2. Decisions with too many rules (e.g. more than 10,000). Time needed for knowledge base construction would be too long, as would the search time required to find a solution.

3. Decisions that are well-structured. The advantages of expert systems are not relevant for well structured numerical problems.

4. Decisions solved by human capabilities, such as decisions that involve pattern recognition elements whose information comes primarily through the sense of sight, smell, or touch.

5. Decisions in wide and shallow domains. Expert systems work best in deep and narrow domains.

6. Decisions that are so new that no experts exist in the area.

7. Decisions involving areas with frequent and substantial disagreement among experts.

Neither of the two semistructured decisions selected for this research have any of the above characteristics. Despite some problems, expert system technology is continuing to grow in this country.

Future Trends of Expert Systems. "Expert systems are the fastest growing segment of that [AI] market, with the number of companies founded to develop expert system products doubling since 1983" (22:64). By building civil engineering expert systems now, we can stay abreast of the AI market (including expert systems), which is predicted to climb from $443 million in 1984 to $4 billion by 1990 (22:63).

Emphasis of Study

This research will involve the selection of domain experts and the query of these experts to determine a list of production rules. A domain expert is defined as "one who is probably better at performing in a domain then those who are not considered to be expert" (16:234). This query of information fits into the broad field of knowledge engineering. Chorafas defines knowledge engineering as the applied-science side of artificial intelligence. The biggest challenge in applied science is the step from knowledge acquisition to the development of rules and the interactive use of those rules (3:78). Knowledge acquisition is "the most important phase of the expert system development" (10:158). Production rules are defined as:

> A primary way of representing knowledge for use in an expert system. The production rule has one or more conditions (the IF part) followed by a conclusion (the THEN part) that is true if the premises are true [16:236].

The final product will be a set of production rules based on the knowledge acquisition process developed in this research. The production rules will be loaded into an expert system shell. An expert system shell is a software tool that takes established production rules and creates a working expert system program. The final product may be used in future research to develop software to automate and integrate the expert system into civil engineering's Workorder Information Management System (WIMS).

II. Knowledge Familiarization

Overview

This chapter reviews the literature to better understand the issues related to building an expert system. It includes a review of expert system components, knowledge engineering, knowledge acquisition, domain expert selection, and finally a summary of Air Force Regulation 85-2, the draft regulation for AFR 85-1 which is expected to be implemented soon.

Components of an Expert System

It is easier to understand an expert system if it is considered as a whole made of component parts.

Complete System. Williamson uses the analogy of a milking stool in describing the components of an expert system. These components include the knowledge base, inference engine, and user information.

> Think of an expert system as a three-legged milking stool. One leg consists of the system's knowledge base: rules, static data, good guesses--anything an expert puts to use in solving a problem. The second leg is the expert system's inference engine: the way it applies information in the knowledge base to the problem at hand, the route it takes in applying data to the rules of the case. The third leg--without the system cannot stand--consists of information about a specific problem that the user wants solved [26:51-52].

Keim further expands the expert system by stating, "An expert system is comprised of a number of components that work together to produce the desired results" (15:65). The components include: the knowledge base, the inference

engine, the explanation subsystem, the knowledge acquisition subsystem, and the human interface (see Fig. 1) (15:8).

The knowledge base and knowledge acquisition subsystem can be considered one leg, while the explanation subsystem and human interface make the second leg. The inference engine can then be considered the critical third leg.

Knowledge Base. Lampert says the knowledge base is the item 'which incorporates the knowledge of an expert or group of experts in a specific area' (17:140). The power of an expert system comes from its knowledge base. The quality of this component is a major determinant of the performance level of the expert system (15:8; 17:140).

Inference Engine. 'The second major component of an expert system is the Inference Engine, a generalized reasoning mechanism which interprets the rules in the knowledge base and performs logical inferences' (15:9). There are three commonly used inference methods: data driven (forward chaining), goal drive (backward chaining),and mixed (15:9).

With forward chaining, the user must begin by entering a set of known facts. The program may respond quickly with an answer, or it may behave in an aimless fashion, asking apparently unrelated questions attempting to arrive at some conclusion (15:9). According to Keller, 'Forward chaining is best used when we are trying to answer a question which

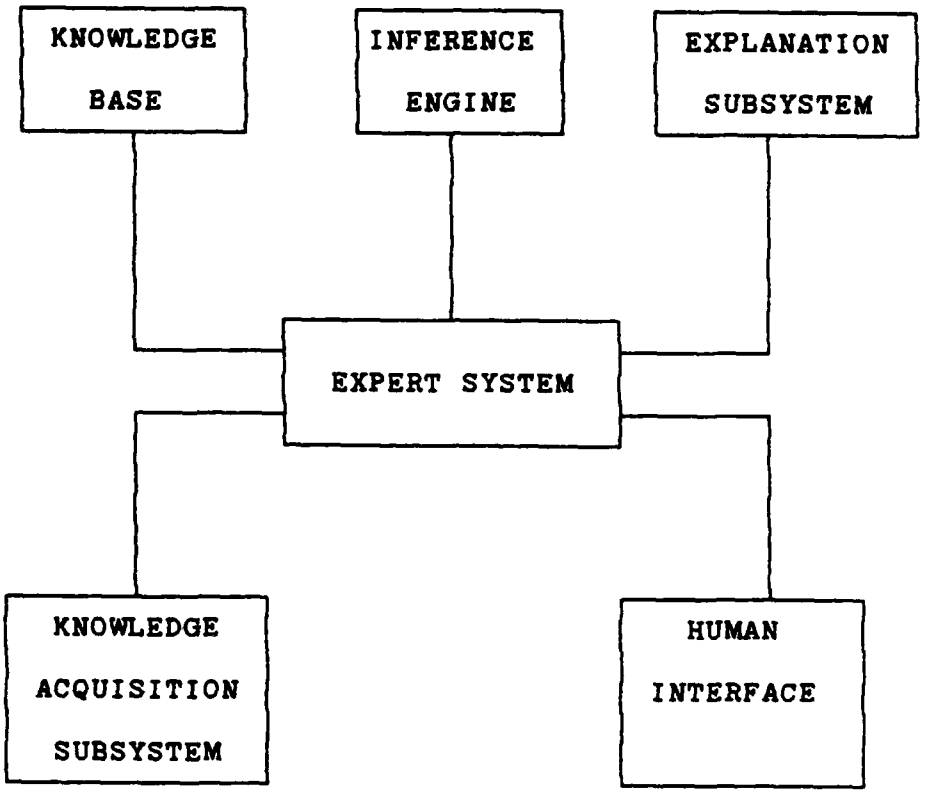


Figure 1

Components of an Expert System

gives us some data and asks us to find some conclusion" (16:146). The main problem with forward chaining is it typically has no basis for choosing one path over another and thus may search the entire knowledge base before coming up with an answer (16:146).

Backward chaining on the other hand, only considers rules which lead to a particular goal. It works backwards through its rules in an attempt to prove the goal (15:9). Backward chaining has the primary advantage of neglecting unrelated rules. The primary disadvantage is that the user is not able to easily volunteer information pertaining to the problem (15:9).

> Backward chaining is probably a good inference technique candidate when you can reasonably guess at what the conclusion might be. There are at least two good reasons for this, one being that the logic train will be short and direct as possible in your knowledge base, the other being that the user questioning is focused on the goal being proved. Most commercial shells which offer only one inference technique will offer backward chaining. If you have no idea what the conclusion is in a given situation, however, then backward chaining is probably no more efficient then forward chaining [16:148].

Explanation Subsystem. The primary goal of an explanation subsystem is to display a comprehensive account of its actions (4:81). The explanation subsystem is primarily needed so an expert system can explain its line of reasoning to the user if and when the user requests an explanation (15:9). In addition to the three key components, one must also have knowledge build-up and human interface capability.

Knowledge Acquisition Subsystem. The knowledge acquisition subsystem is required to allow the expert system to grow. This subsystem allows the user to add new rules and facts or delete existing ones (15:10). The ability to gain new knowledge allows the knowledge base to grow in the same manner an expert's knowledge increases with experience.

Human Interface. The human interface should translate input from the user and the domain expert into internal forms and then make the system's output understandable to the user (15:10). The human interface element should be aimed at a variety of users, from the novice to the most experienced.

Knowledge Engineering

Chorafas states that "knowledge engineering is the development, production, and distribution of intelligence through man-made systems" (3:78). Knowledge engineering can be a slow and inexact process (1:73). The primary task of the knowledge engineer is to identify critical inputs and outputs, discern the inner process that transfers the inputs into outputs, and integrate this knowledge into the proper computer program (27:139).

Sell discusses that the knowledge engineer should be aware of three different types of knowledge.

> The first is the simplest, and goes by the name of 'perceptual knowledge.' This covers knowledge of simple facts and relationships,.... Strictly speaking expert systems do not need to hold these items.... The next level up we find what most people would consider knowledge: concepts and relationships. Here we find scientific laws....

> We also find heuristic observations.... But, there is a third and extremely important level. Experts bring to bear on a problem not only their scientific knowledge and their experience, but also knowledge of how to set about a problem, how to go around difficulties, what else to try when they get stuck. This could be termed an expert's 'strategic knowledge' [23:29-30].

These three levels represent in order, both the power of the knowledge and difficulty in capturing it (1:76). A subset of knowledge engineering is knowledge acquisition.

Knowledge Acquisition

Knowledge acquisition is the most important phase of expert system development (10:158). According to Robert Keller in his book Expert System Technology, knowledge acquisition means acquiring knowledge of a particular domain from some source, usually human, and building this knowledge into a computer system (16:21). Waterman expands the sources for knowledge acquisition to textbooks, reports, databases, case studies, empirical data, and personal experience. Acquiring the knowledge needed to power an expert system and structuring that knowledge into a usable form is one of the primary difficulties in expert system development (24:52,152).

Difficulties with Knowledge Acquisition. The literature points out that the knowledge engineering paradox, time, inaccurate statements, and establishing trust between the expert and knowledge engineer are all difficulties associated with knowledge acquisition. These

difficulties require us to confine knowledge acquisition activities to a very small number of domain experts (16:3).

Sell exclaims there is no science involved in knowledge acquisition. Proposed methods appear to work only for some individuals or in some cases. "What advice is available tends to be ad-hoc and often no more than common sense" (23:30-31). The fact that no clear method for knowledge acquisition exists, adds to the need for studying and understanding the difficulties associated with knowledge acquisition.

Knowledge Engineering Paradox. Waterman narrows in on the ability of the expert to describe his knowledge as the basis for the difficulties in knowledge acquisition. Waterman describes this difficulty as the knowledge engineering paradox. "The more competent domain experts become, the less able they are to describe the knowledge they use to solve problems" (24:154).

Time. According to Weiss, time is another reason why knowledge acquisition is difficult. Acquiring knowledge from an expert is a gradual process which may stretch over weeks, months, or even years. Weiss further explains that the issue of time may be directly related to the expert system designer. Some projects have spent long periods of time on expert interviews and literature searches without any clear direction on how to proceed (25:105).

Inaccurate Statements. Another reason for the difficulty of knowledge acquisition is due to inaccurate

statements of the expert. As a result of the paradox concept, Waterman tells us not to believe everything experts say (24:154). Chorafas also adds that an expert who can easily articulate what is done can be very wrong. 'That's why it is sometimes wise to observe the expert actually solve a problem and check that both the information and logic used are those the expert claims to use' (3:107-108). By double checking the expert you may find that, more than once, the human expert will be surprised by what the knowledge engineers have encoded (25:45-56).

Establishing Trust. Even though there are difficulties in knowledge acquisition, trust between the expert and knowledge engineer can overcome some of the difficulties.

> The experts must come to trust the interviewer enough to overcome any fears or insecurities felt about the expert system process. He may feel insecure about loosing his job, or feel threatened by the encroachment of computers into his private domain, or he may not want to subject his problem-solving methods to the scrutiny of other human experts [2:28].

Methods of Knowledge Acquisition

The literature discusses several techniques for acquiring knowledge from the expert. Each of these techniques could be used under certain circumstances. However, the technique must adapt to the expert's knowledge.

The expert uses many varied sources of knowledge to solve problems. 'The approach of capturing his knowledge must proceed on many facets simultaneously' (7:4). This

multifaceted approach requires an experienced knowledge engineer. The knowledge engineer who is a novice in the particular field of interest may actually inhibit the expert. The need for preparation is not always appreciated. The knowledge engineer should read about the domain to understand the basic concepts and jargon before approaching the knowledge acquisition process (3:107). Maital explains the primary objective behind knowledge acquisition.

> Generally, knowledge engineers trail a human expert for a year or more, trying to encode what the expert knows into a set of 'IF-THEN' rules. Some of those rules are clear cut, but others are ambiguous 'IF X (to some degree) and Y (to some extent) THEN Z is probably true.' It is in these ambiguous rules that human expert's 'lore' is captured. Doing so may take many iterations [19:46].

Table I depicts specific techniques which Waterman recommends for acquiring knowledge from the expert. He explains that on-site observation gives the knowledge engineer insight into the complexity of the problem and type of interface facility needed to use the finished system in the field. Throughout problem discussion, the objective is to determine and understand how the expert organizes knowledge about each problem, represents concepts and hypotheses, and handles inconsistent, inaccurate, or imprecise knowledge and data related to the problem (24:159).

During problem analysis, the expert is given real problems. The knowledge engineer then attempts to determine

Table I

Techniques for Extracting Knowledge (24:158)

Method	Description
On-Site observation	Watch the expert solving real problems on the job.
Problem discussion	Explore the kinds of data, knowledge, and procedures needed to solve specific problems.
Problem description	Have the expert describe a typical problem for each category of answer in the domain.
Problem analysis	Present the expert with a series of realistic problems to solve aloud, probing for the rationale behind the reasoning steps
System refinement	Have the expert give you a series of problems to solve using the rules acquired from the interview.
System examination	Have the expert examine and critique the prototype system's rules and control structure.
System validation	Present the cases solved by the expert and prototype system to other outside experts.

which goals the expert is pursuing to solve the problems and how these goals work together (1:84). The knowledge engineer is observing how the expert translates the inputs into outputs (27:139).

Interviews. Sell points out that "at the moment, most knowledge-based systems are built using interviewing and literature techniques" (23:29). Fraser defines two different types of interviews that can be used during the knowledge acquisition phase -- the unstructured interview and the open-ended interview. Each type has its advantages and disadvantages.

Unstructured Interview. This type is primarily used when the knowledge engineer has very little background in the domain area. Often called an exploratory interview, neither the specific questions nor the answers are anticipated. Instead, the answer to one question leads the knowledge engineer to the next question. Unstructured interviews permit the expert, rather than the knowledge engineer, to introduce concepts and vocabulary, giving the engineer an initial sense of the domain (9:11-12).

Open-Ended Interview. This type of interview is primarily used when the knowledge engineer has some background in the specific domain. Open-ended interviews introduce structure into the knowledge acquisition process. The objective of introducing structure is to better control the information, not the expert. Questions are specified by the interviewer, but responses by the expert are neither

anticipated nor standardized. Open-ended interviews enable the interviewer to determine the level of questioning and provide a focus that makes expert digressions more tolerable. Digressions are not only highly informative, they are also a way an expert assures himself that important information, perhaps with life and death implications has been conveyed. Pre-set questions will refocus the interview after a digression. Open-ended interviews require that the knowledge engineer be more or less aware of the kind of knowledge he is after (9:13).

Fraser goes on to point out that, two of the problems with open-ended interviewing are that important issues may not be anticipated by the questions, or the questions themselves may miss the point. It is important for the knowledge engineer to remain responsive to what is being said and to the experts nonverbal reactions (9:14).

Role of the Knowledge Engineer. As long as the knowledge acquisition process remains manual (or nearly so), the most prominent knowledge acquisition method is the interview with the expert (3:105). The knowledge engineer must take an active role during the interview.

> The role of the knowledge engineer is to interpret the expert's answers to questions with respect to knowledge and the method of knowledge representation, to integrate the expert's answers into the growing knowledge bank, to draw analogies to help the expert structure (or remember) important aspects of the expert's own knowledge in the application domain, and to pose counter examples which seem to violate the expert's hypotheses [3:105].

An active role includes asking questions, suggesting possible rationales, and hypothesizing concepts and rules during the interview (24:157-158). Throughout questioning, the knowledge engineer should not reject the expert's first answers. Instead, the knowledge engineer should impress on the expert the need to justify conclusions (3:107).

Bonnie Fraser cautions the knowledge engineer not to take over the interview by continuously interrupting the expert. This constant interruption may provoke resentment by rejecting the expert's description of his reasoning and pressing him to justify every conclusion (9:2).

With each technique the knowledge engineer uses, he or she must realize that certain flaws exist. During knowledge acquisition, the information from an interview may be incomplete, and require interpretation (3:107).

Refining the Knowledge Base

Whatever method of knowledge acquisition is used, several authors give advise to help refine the product. A better approach than generalized commentaries for refining the knowledge base is to include the expert in feedback. Take the emerging expert system back to the expert for comment. This feedback will elicit more of the expert's knowledge and help in tuning the contents of the knowledge base (3:106; 9:3; 25:106). Weiss goes on to say that "it is sometimes amazing to watch the pace of useful knowledge acquisition accelerate once a prototype model has been built" (25:105).

Expert Selection

One of the first major knowledge acquisition problems is to find a cooperative 'star' expert who has the time available to dedicate to the project (9:4).

Definition of an Expert. An expert is someone who:

1. Has a large knowledge domain in the form of facts and rules.

2. Has individual experience not found in the literature of the domain or going beyond what is currently available.

3. Is widely recognized as being able to solve a particular type of problem that most other people cannot solve as efficiently or effectively (3:102; 12:31).

Number of Experts Required. One of the most controversial issue regarding expert selection appears to be the question of using single verses multiple experts. Most knowledge engineering projects to date have relied on a single expert (1:72). Maital supports a single expert philosophy. The expert system is a result of close interaction between a human expert (usually one) and knowledge engineers attempting to capture the expert's knowledge (19:45). Knowledge engineers typically prefer to work with only one domain expert (or at least only one expert at a time) because different experts tend to have different methods for solving problems (15:11).

Waterman argues for multiple experts. Multiple experts alleviate evaluation problems in domains where experts

disagree (24:133). In complex domains such as medicine or engineering, any one expert is often very knowledgeable about only a small subset of tasks in the domain (21:32).

The points of inconsistency and inefficiency must be addressed when working with multiple experts. The use of one or more experts will increase the amount of inconsistencies into the knowledge base (24:182).

Keller sums it all up by recommending the number of experts be kept to a minimum.

> ...the actual number of experts required may vary from situation to situation. In any case, I would recommend starting with as few experts as possible -- otherwise the amount of uncertainty about the decision process may become overwhelming when all you're trying to do is set up some widely accepted ground rules for the domain [16:30].

Selecting the Expert. Mittal and Dym recommend the peer group determine who are the real experts (21:35). Waterman suggests the competent expert should be selected based on the opinions of his peers in the target domain (24:192; 21:33).

Keller focuses in on attitude in selecting the expert with the right qualities. Keller concludes that the expert's attitude is critical to the success of a knowledge-based system project. Some experts feel that an expert system is a threat to their job. Keller warns:

> I have found it useful to categorize them (experts) broadly as willing and able, uninterested, or hostile. The expert being willing and able is, of course, the desirable situation. Anything less than that kind of participation by the expert will make the project both more lengthy and more difficult to complete successfully. The hostile

expert is to be avoided if at all possible [16:31].

Air Force Regulation 85-2

Draft AFR 85-2, Operations Management, outlines the current thinking of how work requests will and, in most cases, are being processed in civil engineering. The various rules from AFR 85-2 pertaining to the domain decisions are summarized below.

Written Requests. AF Form 332, Base Civil Engineer (BCE) Work Request, is the primary document for requesting and approving work requirements. It is also the primary document for authorizing work requirements, except for the following cases:

A. Work in excess of the Installation Commander's approval level.

B. Work funded by major command.

C. Work to be accomplished by contract within the Installation Commander's approval authority and MAJCOM requires additional approval documentation.

D. Work classified as a local manufacture of a supply item. For such a case a DD Form 1348-1, DOD Single Line Item Release/Receipt Document, is required.

E. Self-help work which is:

1. The homeowner's responsibility as described in AFR 90-1, Family Housing Management.

2. Minor maintenance and repair work which

can be accomplished by over-the-counter materials from the self-help store.

F. Work not requiring individual costing which is properly authorized by the collection work order list, AF Forms 1219 (BCE Multicraft Job Order), AF Forms 1879 (BCE Job Order Record), or the recurring work program.

If the scope of work requested does not automatically qualify for categorical exclusion from further environmental analysis, an AF Form 813, Request for Environmental Impact Analysis, should accompany the AF Form 332. "Fire protection coordination should be obtained on all requested work when either life, safety, fire alarm or suppression systems, fire rating of materials, fire protection access to an area or facility, or fire protection criteria is affected by the proposed work" (5:42).

In addition to the work request, engineering is required to prepare a DD Form 1391, Military Construction Project Data, if the work requested is classified as:

A. Minor construction and is to be accomplished by contract.

B. Maintenance or repair and is above the Installation Commander's approval authority.

C. Maintenance, repair, or minor construction and is to be funded by MAJCOM.

Job Orders. Job orders are intended for small jobs and should involve minimial paperwork. The job order system is a fast way to authorize minor facility maintenance and

repair not requiring detailed planning. The types of job orders include: emergency, urgent, routine, structural maintenance and repair team (SMART), and Military Family Housing (MFH) renovation job orders (5:54).

Job orders are used to authorize a vast majority of the small jobs on base, but they should not be used to authorize:

A. Minor construction work involving leased facilities.

B. Work done by contract.

C. Services from Civil Engineering except entomology services.

D. Recurring work.

E. Work that must be capitalized on real property records.

Summary

The knowledge familiarization chapter has brought to light several key points. Identifying the right expert is critical. Methods of extracting the expert's knowledge are numerous. Irregardless of the method choosen for knowledge acquistion, the knowledge engineer must go back to the expert to validate his conclusions. This paper primarily addresses the knowledge acquisition phase. According to some literature, this is the toughest phase of expert system development.

A major step in the knowledge acquisition phase is identifying the right expert. The literature points out

that peers are one of the best groups for identifying the domain experts. The expert must not only have the proper knowledge, he or she must be willing to cooperate with the expert system developers. Several authors warn about the problems caused by an uncooperative expert. The literature also points out the paradox that the more qualified an expert is, the harder it is for the knowledge engineer to extract the knowledge.

The literature identifies several methods of drawing out the expert's knowledge. The most common method of knowledge acquisition is the interview. The actual interview can be conducted several ways depending on the experience and background of the knowledge engineer. An open-ended interview should be used if the knowledge engineer has some background or experience in the area of interest. A structured interview should be used when the knowledge engineer is not familiar with the domain of interest.

Several of the experts pointed out that you need to keep going back to the domain expert to refine and verify your conclusions. The initial interpretation of the expert system may be incorrect. Developing a prototype expert system is critical element in developing a complete expert system. The rate at which knowledge is gained increases when a prototype expert system is developed.

Air Force Draft Regulation 85-2 clearly has some rules that apply to the domain area of this research. The rules

primarily explain when we should not use a work request or job order to authorize certain jobs. Each one of these rules should be brought into the knowledge base.

III. Methodology

Research Approach

Knowledge acquisition is the process of acquiring detailed knowledge from expert sources. The following steps will be used in the knowledge acquisition phase of this research.

1. Become familiar with the domain of interest (CE Operations).

2. Select domain experts.

3. Interview domain experts to extract initial knowledge base.

4. Display the knowledge gathered in the first interview in IF/THEN rule format.

5. Interview domain experts a second time to verify initial interpretation of knowledge rules.

6. Finalize knowledge base in procedural rule format.

7. Automate knowledge base through an expert system shell.

8. Validate the expert system.

Become Familiar with Domain. A detailed literature review in Chapter II summarized the nature of knowledge acquisition. This understanding is called knowledge discovery or knowledge familiarization. It describes the knowledge gained by extensive study of professional magazines, academic journals, novels, textbooks, instruction

manuals, physical facilities, or any other appropriate sources (27:164).

The knowledge familiarization process also includes operating several existing expert systems and developing prototype programs based on personal knowledge. This hands on experience clarifies the structure, operation, capabilities, and limitations of expert systems faster than any other method (14).

Select Domain Experts. Many Air Force experts exist in this area. Any Chief of Production Control at any of the active 138 Air Force installations could be considered an expert. Allowing the MAJCOMs to select an experienced, willing, and articulate individual, will give the researcher a smaller sample of experts to review as potential domain experts. A letter (Appendix B) requesting domain expert nominees will be sent to the Military Airlift Command (MAC), Tactical Air Command (TAC), Strategic Air Command (SAC), and Air Force Logistics Command (AFLC) civil engineering headquarters.

From the peer selections, two expert candidates will be selected to answer research question two, which asks who are the domain experts. Although most knowledge engineering projects have relied on a single expert, two experts will be used in this research to increase the validity of the knowledge base (1:72). These two candidates will be selected based on the following criteria.

1. Must be presently working at base level.

2. Should have a minimum of two years experience in civil engineering operations.

The most experienced nominees will be contacted to determine if they are willing to participate in the knowledge acquisition interviews. Willingness to participate is crucial because, 'Most experts view the development of expert systems as a threat to their position or status' (27:168).

Interviews. Steps three and five involve interviewing the domain experts in an attempt to extract their knowledge. These steps will answer research question three, which is to determine the thought process used by the experts when they respond to specific semistructured decisions. The most practical method (open-ended interview) was selected because the researcher has prior knowledge in civil engineering operations.

The domain expert may require documents and examples of reports, therefore interviews will be conducted at the location of each domain expert. Interviews will be loosely structured with the researcher leading the domain expert with the open-ended questions listed in Appendix C (27:172). The first interview will start with an explanation of what an expert system is and then the specific reason for the interview. The goal is to acquire the expert's knowledge and/or capture the heuristics and rules they use to confront the decisions in question.

Knowledge Display and Translation. From the interview answers and comments, a set of production rules and conditions will be developed. The IF/THEN format for knowledge bases explained in Chapter II will be the primary method of representing the knowledge base. After the first interview, an initial knowledge base of rules will be built.

The domain experts will then be revisited for a second interview to validate the researcher's interpretation of their knowledge base. The main emphasis of the second interview will be to validate the translation of the initial rules.

Automate Knowledge Base. The knowledge base will be incorporated into 'VP-Expert,' a rule-based expert system development tool by Paperback Software. Automation is required to facilitate testing and expansion of the knowledge base. It's anticipated that the large number of rules and complexity will hamper manual expansion and validity testing.

VP-Expert was selected as the shell because the author was familiar with the language and inference engine. VP-Expert is also very user friendly during the debugging phase of programming. The programmer is able to slow down the inference engine and set up a 'tracer' to track the logic of the knowledge base during a consultation. This tracer shows which rules were used during a consultation,

allowing the programmer to follow the knowledge base's logic.

VP-Expert has limitations. The variable length is restricted to only 20 characters. Therefore, many of the rules will be condensed into variables in order for VP-Expert to except them. The editor in VP-Expert also has drawbacks. While using the editor, none of the lines in a program are numbered. This requires the programmer to count the actual lines every time VP-Expert indicates an error exists. Editing becomes quite time consuming when the programmer must count 100 lines to find the area where an error exists.

Validity Testing. After automating the knowledge base, the expert system's recommendations will be compared to recommendations made at Wright-Patterson AFB Civil Engineering on how to accomplish certain work requests. Thirty new work requests will be reviewed by personnel at Wright-Patterson AFB with a recommendation made as to approve or disapprove each work request, and if approved, to determine how they should be accomplished (job order, work order, or contract).

The automated expert system will then be applied to the same work requests. The expert system will independently recommend approval or disapproval of each work request and recommend the method of accomplishment for approved work requests. Any conflicts will be corrected on site. The

knowledge engineer will determine whether new rules should be added to the knowledge base.

Summary

This chapter discussed the methodology used to answer the research questions in Chapter I. Knowledge familiarization was required to determine how the knowledge acquisition phase would take place. Certain knowledge acquisition steps were developed based on the literature review. A peer nomination of domain experts will be used to select two domain experts. A series of detailed interviews will then be conducted to draw out the domain expert's knowledge. Based on this knowledge an automated expert system will be developed. Thirty work requests will be reviewed by both the expert system and Wright Patterson AFB personnel to validate the expert system's logic.

IV. Results and Other Findings

Overview

This chapter presents the results of the expert selection phase and the knowledge acquisition steps explained in Chapter III.

Expert Selection

Seven expert candidate names were identified by major commands in response to the request in Appendix B. They are listed in Appendix D.

Candidate Evaluation. Two expert nominees were suggested by HQ SAC. One was currently working at the headquarters, the other was working at base level.

HQ AFLC responded with one candidate. This candidate is currently working as the Chief of Operations at Wright Patterson AFB. The close proximity of this expert nominee with the researcher, make HQ AFLC's candidate a desirable choice.

The two candidates nominated by HQ MAC are currently not working at base level civil engineering. One of the criteria established in Chapter III states that the experts should be currently working in the area of interest (civil engineering operations).

Each of the candidates from HQ TAC are currently working at base level civil engineering. However, HQ TAC/DEM expressed that the Base Commander or higher authority are the only individuals who can approve or

disapprove a work requirement in civil engineering. It is this researcher's opinion that HQ TAC/DEM related major construction projects with the term work requirement rather than work requested an Air Force Form 332.

Candidate Selection. Based on the above information, the two experts will be Lt Col Mike Lemarr, 2750 ABW/DEM and CMSgt John E. Gaulin, 55 CSG/DEM. Lt Col Lemarr was primarily selected due to the fact that he is close to the researcher and thus easily accessible. CMSgt Gaulin was selected based on his perceived willingness to help the research effort. Candidates from MAC were eliminated because they were not presently working at base level. The TAC nominees were received after Lt Col Lemarr and CMSgt were selected.

Initial Knowledge Acquisition

Once the domain experts were selected, the knowledge acquisition process started. The initial interview started with CMSgt Gaulin (11).

Initial Interview. The purpose and intent of expert systems in civil engineering was explained to CMSgt Gaulin (Expert #1) before starting the open-ended questions. The entire interview was recorded allowing the researcher to concentrate on the expert's replies and non-verbal gestures. Expert #1 was very willing to discuss all aspects of the decisions in detail and interruptions were kept to a minimum. The prepared questions were only used as a lead-in

to prompt the expert to start thinking about the decisions of interest.

Several scenarios and logic patterns were discussed with the expert. Most of the knowledge was gained when specific examples were discussed. Each example brought in several new rules and tested other rules already established.

At this point, before the knowledge was structured in any way, the shear volume was overwhelming. The actual number of rules was unknown, but the thought process and heuristics appeared to be quite complicated. Prior to interviewing Lt Col Lemarr, the knowledge was grouped into modules to help clarify the logic and compare it to the anticipated responses of Lt Col Lemarr.

The initial interview with Lt Col Lemarr (Expert #2) followed the same approach as the initial interview with expert #1 (18). But, the results were quite different. The same enthusiasm existed for solving the problem, but expert #2 explained that most of the decisions regarding work requests were done by the Work Order Review Panel (WORP). As the Chief of Operations, expert #2 spends most of his time dealing with policy issues and major problem work requests and depends upon his staff to manage the details and suggest actions. Mr Arlyn G Johnson, Chief, Production Control in the Operations Branch makes the initial review of all work requests before they are reviewed by WORP. Mr Johnson makes recommendations in the same manner as expert

#1. Mr Johnson acts as the expert decision maker and advisor for the WORP and Lt Col Lemarr.

At this time, a decision was made to continue the initial knowledge acquisition process with expert #1 and then use Mr Johnson in the second interview phase to verify the rules and logic established by expert #1.

Initial Knowledge Translation. The literature expressed that knowledge acquisition was the most difficult portion of building an expert system. But, displaying the knowledge gained, or knowledge representation, turned out to be the most difficult step within knowledge acquisition.

Much time was spent after the first interviews attempting to display the knowledge gained. Initially a tree diagram was attempted, but the number of rules was too great and the tree became too large to comprehend. Finally, the thought pattern appeared to be modular. That is, after a few basic questions a work request would fall into one of several categories. Then, depending on the category, other questions were asked to determine how the work request should be accomplished or if it should be disapproved. A concept map became the easiest method for displaying the knowledge gained by the initial interviews. A copy of the final concept map is displayed in Appendix E.

Second Knowledge Acquisition

Second Interview. Expert #1 was again visited after the logic pattern or thought process established in the first interview was translated into a concept map. A large

amount of knowledge was gained during the second interview with expert #1 (11). The concept map was used as a drawing board to follow the logic patterns discussed in the second interview. Several case examples were used to explain and expand the rules and procedures established from the first interview. The cases attempted to identify the change over point between different alternatives. Several times expert #1 would stop the discussion and make corrections to previous rules.

At the end of every example or recommendation the expert was asked to give a confidence factor. The confidence factor was explained to expert #1 as a number (0-100) that represented how confident the expert felt with a specific recommendation.

Second Knowledge Translation. As a result of the final concept map, a number of IF/THEN rules were written. These rules are listed in Appendix F. Although it is quite clear that the rules do not encompass all possible work request scenarios, there is a large enough knowledge base to develop a prototype expert system. Each rule follows a particular path of the concept map. As an example, Rule #9 is listed below.

Rule #9 Source: Gaulin

IF:

Work request description is not CE responsibility
AND
The proper approval authority wants it done AND
The scope of work is not clear AND
The description of work is not unique to one superintendent

THEN:

Send work request to Planning for 'Shot-Gun' estimate (Confidence 100%)

Rule #9 is based on the scenario that CE will, on occasion, receive work requests that are not exactly their responsibility, yet the BCE or some proper approval authority would still like the work accomplished. This rule further determines if the scope of work is not clear and whether the work request is unique to one superintendent. If all the conditions of rule #9 are true, the expert system will recommend, with 100% confidence, to send the work request to planning to determine the scope and give a 'Shot-Gun' estimate. A 'Shot-Gun' estimate is a common term in CE that refers to a quick estimate of man-hours, materials, and funds required to accomplish the work request in question.

Automation

Once the IF/THEN rules were established, the expert system shell VP-Expert was used to represent the rules in an automated program. The program is listed in Appendix G.

As an example showing how the rules were transferred into VP-Expert, rule #9, explained above, is shown as seen in the VP-Expert program.

```
RULE 9
     IF   Status=Hot AND
          Scope=Unclear AND
          Super_Stat=Varied

     THEN
          Recommendation=Send_to_Planning
BECAUSE 'We are trying to determine if Planning needs
to review the particular work request before approval
is given.';
```

In VP-Expert, rule #9 starts by searching to determine if Status = Hot. This is based on Rule #6.5 shown below.

RULE 6.5

IF Description=Others AND
Approval_Auth=Boss_says_do_IT

THEN
Status=Hot

BECAUSE 'Even though the work may not be civil engineering's responsibility, the mission or our boss may require us to do the work. Don't always throw the regulations out and look for reasons why we can't do work.';

Rule #6.5 states that if the work request is not CE responsibility and the proper approval authority wants it done, then the status of the work request is 'Hot.' The 'BECAUSE' statement is further explanation available to the user during a consultation. If VP-Expert's rule #6.5 is true then part of rule #9 is satisfied. The other two conditions are determined through ASK statements.

ASK Scope: 'What is the scope of work? Is it clear or unclear... in other words do you have a feel for the amount of man-hours and funding required?';

CHOICES Scope: Clear, Unclear;

The ASK statements prompt the user for a response concerning a specific variable or condition. The rule numbers in Appendix F correspond to the rule numbers in Appendix G.

Validation

With a solid understanding of expert #1's knowledge and an automated knowledge base, 30 work requests from Wright-Patterson AFB were screened to determine how the knowledge base established by expert #1 would react to them.

Mr Arlyn Johnson, the Chief of Production Control, then gave his recommendation as whether to approve each of the 30 work requests and the recommended method of accomplishment. The expert system's knowledge base and Mr Johnson had identical recommendations on 27 of the 30 work requests.

One of the recommendations that did not match involved a work request that Mr Johnson had seen several times earlier. The intent of this expert system was to make a recommendation on work requests being reviewed for the first time.

Another of the recommendations that did not match was due to the fact that Mr Johnson personally did not like to have job orders that involved a large amount of man-hours. He would rather accomplish the work as a work order. This was slightly different then the knowledge extracted from expert #1. Expert #1 had no restriction on the amount of man-hours for a job order, only that no more than three shops could be on one job order and the amount of detailed planning required determined whether the job should be a job order or work order. It is possibile that expert #1 would change his opinion after further reviewing Mr Johnson's logic. Further testing is required before changing the knowledge base in this area.

The final recommendation that did not match involved work classification. One work request reviewed was classified as 'work for others' and thus was reimbursable to CE. Because the work was reimbursable, it was required to

be accomplished as a work order. The expert system recommended the work be accomplished as a job order because it did not know 'work for others' was reimbursable. This was determined to be an error in the knowledge base. Therefore, rule #6.7 was added to correct the knowledge base.

```
RULE 6.7
     IF   Description=Civil_Engineering OR
          Status=Hot AND
          Work_Classification=Work_For_Others

     THEN
          Recommendation=Appr_As_Work_Request
BECAUSE "Work for others is refundable and a AF Form
332 is required to bill the organization requesting the
work.";
```

Matching 27 out of 30 recommendations indicates the knowledge base has some external validity. Correcting the error on one case also shows how flexible the expert system is to change.

To further test the validity of this knowledge base, several other Air Force bases should be visited to test the expert system's logic following the same procedure illustrated above. Any deviations from the expert system's recommendations would be recorded. These deviations would then be consolidated to determine if any pattern exists that would warrant changing the knowledge base.

Summary

Chapter IV presented the results and other findings of the knowledge acquisition phase. A unique method of concept mapping was used during the knowledge acquisition phase to

represent the initial knowledge base and help experts clarify and build the system.

It was discovered that the knowledge used by the experts in civil engineering operations concerning work requests could be captured in an IF/THEN rule format. It was also discovered that each base is peculiar. This uniqueness requires the expert system to be flexible and allow users to customize their needs by adding or deleting certain rules.

Once the IF/THEN rules were established, VP-Expert was used to automate the prototype expert system. This automated expert system was the corner stone required for validating the expert system's logic. Chapter V will present the conclusions drawn from these results and other findings.

V. Summary, Conclusions, and Recommendations

Research Summary

It is possible to develop an expert system based on a semistructured decision in civil engineering. Each civil engineering squadron operates in a slightly different manner. Based on these differences, a generic expert system could be used in the initial phases of development. From this generic program each base can add rules and procedures to the expert system program based on their mode of operation. The prototype expert system developed in this research is generic.

Conclusions

The conclusions discussed in this section are directly related to the research questions developed in Chapter I.

Research Question 1: What are the steps in knowledge acquisition and how are they performed?

Conclusion 1: The actual steps used in knowledge acquisition depend on the domain of interest and the knowledge engineer. Chapter II goes through a detailed description of several procedures used in the knowledge acquisition phase. Based on the knowledge engineer's familiarization with the domain of interest, a set of knowledge acquisition steps were developed in Chapter III for this research project. The most difficult step of knowledge acquisition during this research was knowledge translation. Although it was possible to verbalize the

heuristics and knowledge used by the experts, it was quite difficult to translate the knowledge to paper. Several attempts with tree diagrams failed. Finally, a concept map of the knowledge base appeared to visualize the rules quite well. Both knowledge engineer and expert were able to work off the concept map to refine the knowledge base. Most of the knowledge was gained while using the concept map as a guide.

Research Question 2: Who are the domain experts in the civil engineering field that can supply the knowledge?

Conclusion 2: Based on MAJCOM recognition, seven domain experts were selected as candidates for this research. The candidates are listed in Appendix D. Each candidate is considered an expert in the field of operations by their peers. Of the seven candidates, only two were selected for the knowledge acquisition phase.

Having peers select experts in a particular field is an effective start, but further review of the expert's qualifications is required. One of the experts selected for the knowledge acquisition phase of this research turned out not to be the individual with the expert knowledge. He relied on an individual's expertise below him to make specific recommendations.

Research Question 3: What is the thought process used by experts when responding to the specific semistructured decisions previously identified?

Conclusion 3: The thought process displayed by the experts is illustrated in Appendix E. The thought process follows a logical modular pattern based on years of experience. The experience is clearly evident when trying to accomplish a work request in-house when resources are limited.

Research Question 4: Can the experts' responses be put in rules that correspond to the initial steps of building an expert system?

Conclusion 4: Yes, the responses by the experts can be made to fit the IF/THEN rule format. Appendix F lists the rules in order of the thought process used by the experts. These rules were developed by following a unique path in the concept map. Each path was then put into the IF/THEN rule format. Although the research ended at this point, further analysis of the concept map will show that several internal rules may be developed to remove some of the redundancy seen in Appendix F.

Recommendations for Future Research

The use of expert system in civil engineering is a new and wide-open field. Other areas exist where future research is needed.

A. Expand the expert system developed in this research.

Further expansion of the prototype expert system developed in this research is required. The initial program should be given to several experienced users and the

knowledge base expanded or revised where needed. Each user should be tested individually to determine if the knowledge base follows their logic. The rules in Appendix F can also be further analyzed to determine where choke points and redundancy exist. Once these areas are determined, several internal IF/THEN rules can be developed to reduce the length and delete the redundancy seen in the rules in Appendix F.

B. Automate the work request expert system on WIMS.

Another area of future research for this program is the development of an interface with WIMS. Many of the questions asked by the expert system could be automatically answered by WIMS. Allowing WIMS to answer some of the question will allow the expert system to make a quick recommendation.

C. Develop expert system prototypes of other semistructured decisions.

Many other prototype systems may be developed based on the methodology established in this research paper. Capt Mastrangeli has discovered other semistructured decisions that are commonly found in civil engineering (see Appendix A). Selecting any one of these decisions and applying the methodology developed in this research will create a prototype expert system for further evaluation. Capt Chris Hazen, Graduate Engineering Management (GEM) student in the 88s class at the Air Force School of Systems and Logistics, has written a thesis that determines what

areas within civil engineering could effectively use an expert system (13).

A true expert system is continuously growing and expanding as new knowledge is gained. To make expert systems a reality in civil engineering, more research must be conducted in the areas outlined above.

Appendix A: Top Ten Semistructured Decisions Made by the Chief of Operations and Chief of Requirements in Civil Engineering Operations (20:80,82)

* Decide best method to accomplish work, either through job order, work order, or contract.
* Decide to approve or disapprove work requests.
* Decide on In-service Work Plan (IWP) schedule.
* Decide on work priorities.
* Decide on how to schedule command interest work.
* Decide how to get materials, either through base supply or by local purchase.
* Decide how to classify work [mission essential or nice to have].
* Decide to approve or disapprove walk through for materials.
* Decide on planning schedule.
* Decide on vehicle allocation [size and distribution].

Appendix B: Expert Request Letter

REPLY: Capt Randy Eide, AFIT/LSG, WPAFB, OH 45433-6583

SUBJECT: Request for Experts in the Civil Engineering Operation's Field

TO: HQ SAC/DEM, HQ MAC/DEM, HQ TAC/DEM, HQ AFLC/DEM

1. Previous thesis research at the Air Force Institute of Technology identified several key decisions made by civil engineering managers which could be automated. The two most common decisions are believed to be:

a. Should a particular work request be approved or disapproved?

b. Should identified work be accomplished by job order, work order, or contract?

An expert system computer program could be built to model these decisions. This program would give new managers a useful training tool and experienced managers the ability to compare or validate their decisions. As part of my research at AFIT, I'll be developing the decision rules required to build such a system. A critical element in building such a model is the identification of individuals with extensive background and experience in confronting the above decisions.

2. To help me in my research, I'm asking each major command to identify one or two individuals in the Civil Engineering Operation's field who would feel comfortable addressing and discussing the above decisions. These individuals can be either military or civilian and should have at least two years of base experience. I'll contact all candidates and will interview a select few at their duty location (TDY funded by AFIT). The interviewing process will involve two unstructured interviews, each lasting 4 to 6 hours. I anticipate that the first interview will be conducted in late March with a follow-up interview scheduled in early May of this year.

3. Please send the name, address, and phone number of your candidates to me at AFIT/LSG. With time already playing a crucial role in developing this expert system, your quick review and processing of this request will be greatly appreciated. If you have any questions, please call me at school (AV 785-5435) or home (513-879-7466).

RANDY D EIDE, Capt, USAF

Appendix C: Open-ended Interview Questions

Work Request Approval

1. Do you have the authority to approve and/or disapprove work requests?

2. Is your opinion sometimes solicited in helping to determine whether a work request should be approved or disapproved?

3. If yes to questions (1) or (2), how do you initially view a work request in making the decision to approve or disapprove?

3a. If offered a group of work requests, would you classify them by cost, man-hours, work classification, work description, or something else?

3b. Would you classify this same group of work requests differently in the Spring or Fall?

3c. Do certain organizations or buildings receive priority?

4. How much planning time, if any, goes into a work request before it is reviewed?

5. Can anyone submit a work request?

6. Do you use any BEAMS products in helping you decide whether a work request should be approved or disapproved?

7. Could we go through some work requests requiring approval to review your approval/disapproval methodology?

Approved Work Request Classification

1. Do you have authority to determine whether an approved work request should be accomplished by Job Order, In-House Work Order, or Contract?

2. Is your opinion sometimes solicited in helping to decide whether an approved work request should be accomplished by Job Order, In-House Work Order, or Contract?

3. If either questions (1) or (2) were answered positively:

3a. Are any of the key factors in determining if a work request should be accomplished by Job Order, In-House Work Request, or Contract:

- Estimated Hours
- Estimated Cost
- Type of Work (MC,M,or R)
- Urgency of work
- Description of Work

4. How would you rate the items in question (3a) in order of importance in determining how a work request should be accomplished?

5. Are any organizations or buildings having work accomplished a certain way?

6. Is DEEV consulted before a work request is sent to them as a potential contract?

7. Do you use any BEAMS products to help you decide whether a work request should be accomplished by Job Order,

In-House Work Request, or Contract?

8. Could we go through some approved work requests to review your classification procedure?

Appendix D: Expert Nominees

HQ SAC

CMSgt John E. Gaulin, Offutt AFB

Msgt James E. Tillotson, Whiteman AFB

HQ AFLC

Lt Col Mike Lemarr, Wright Patterson AFB

HQ MAC

Maj John E. Langsdorf, Scott AFB

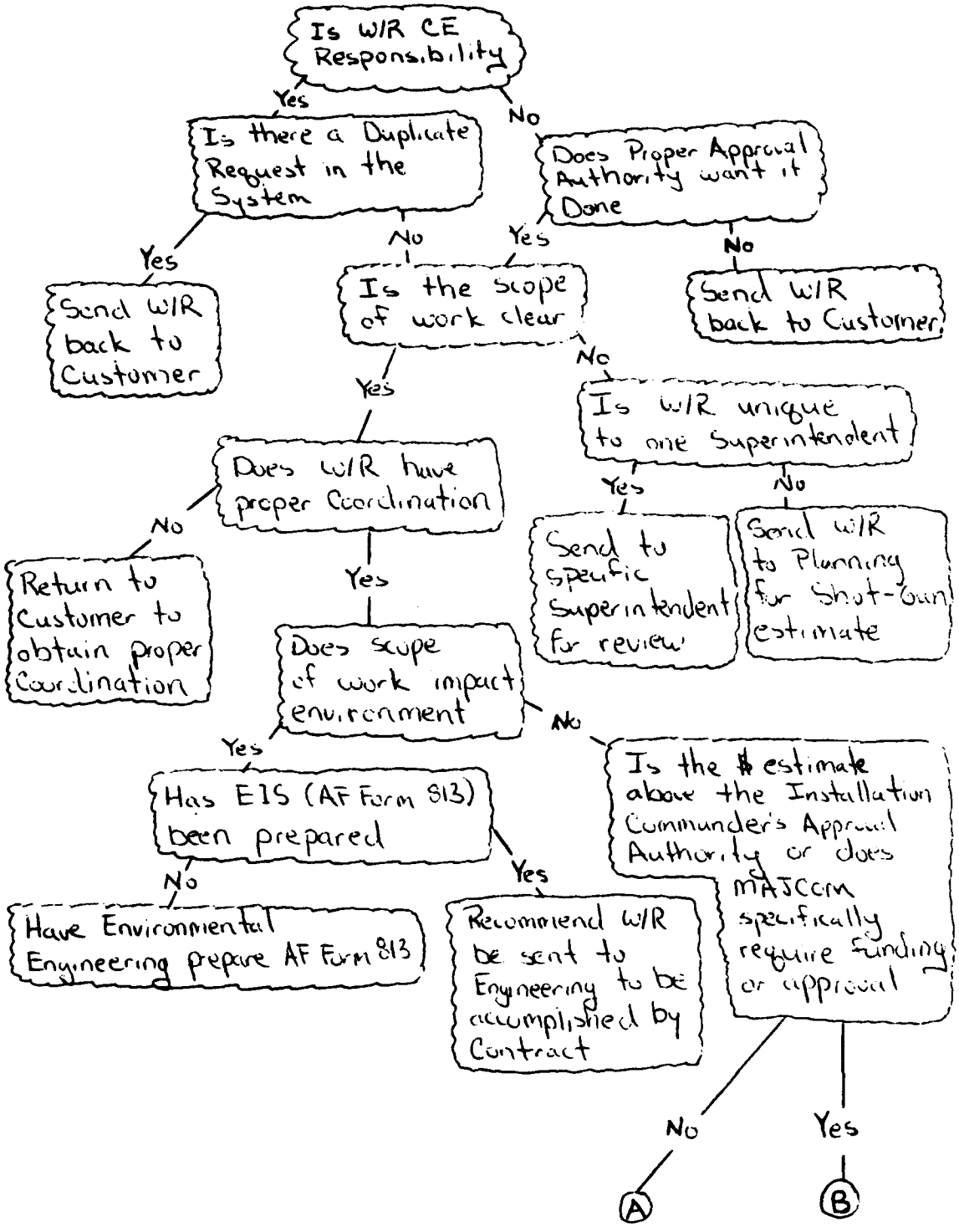
Capt Margann Chisholm, Scott AFB

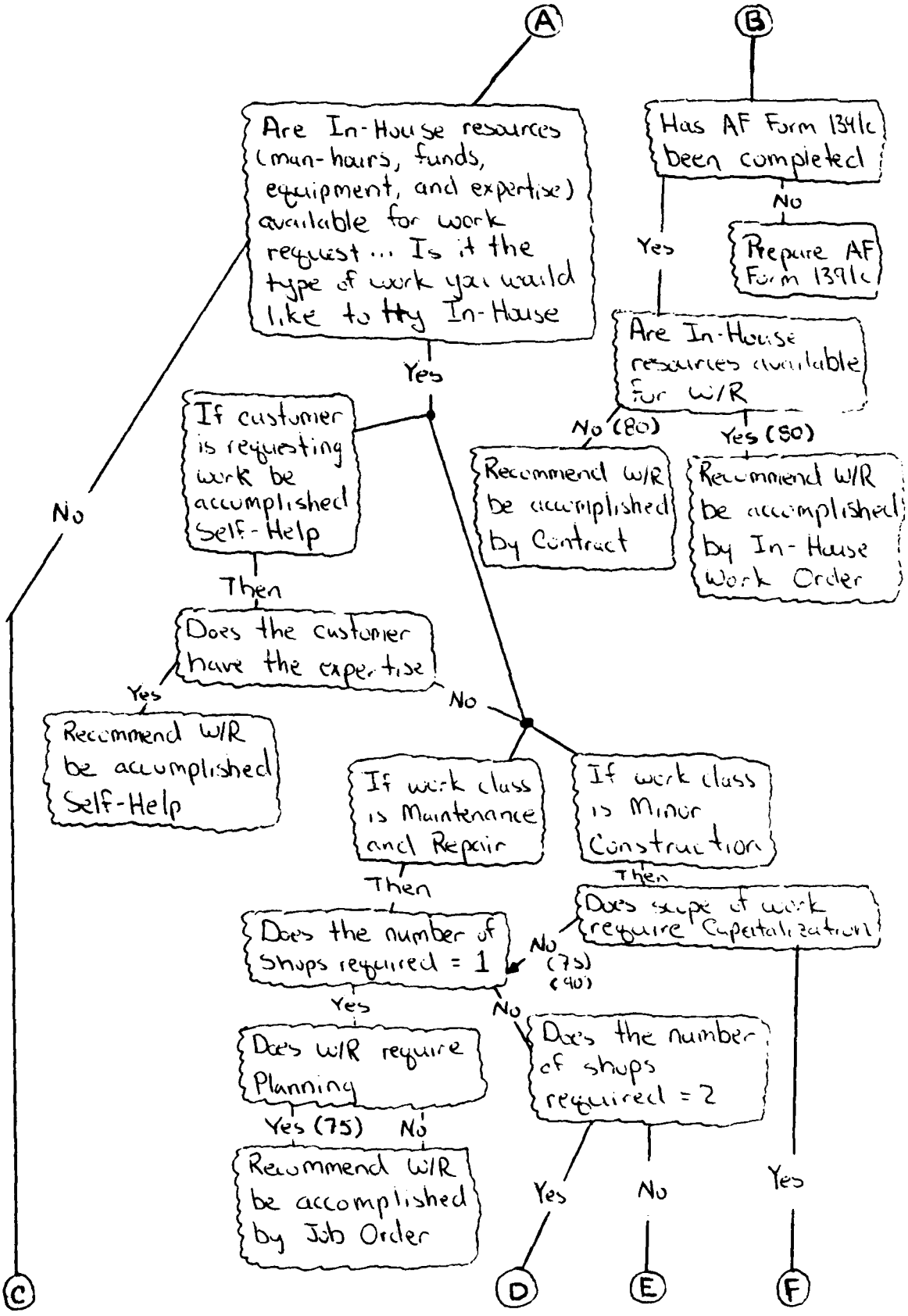
HQ TAC

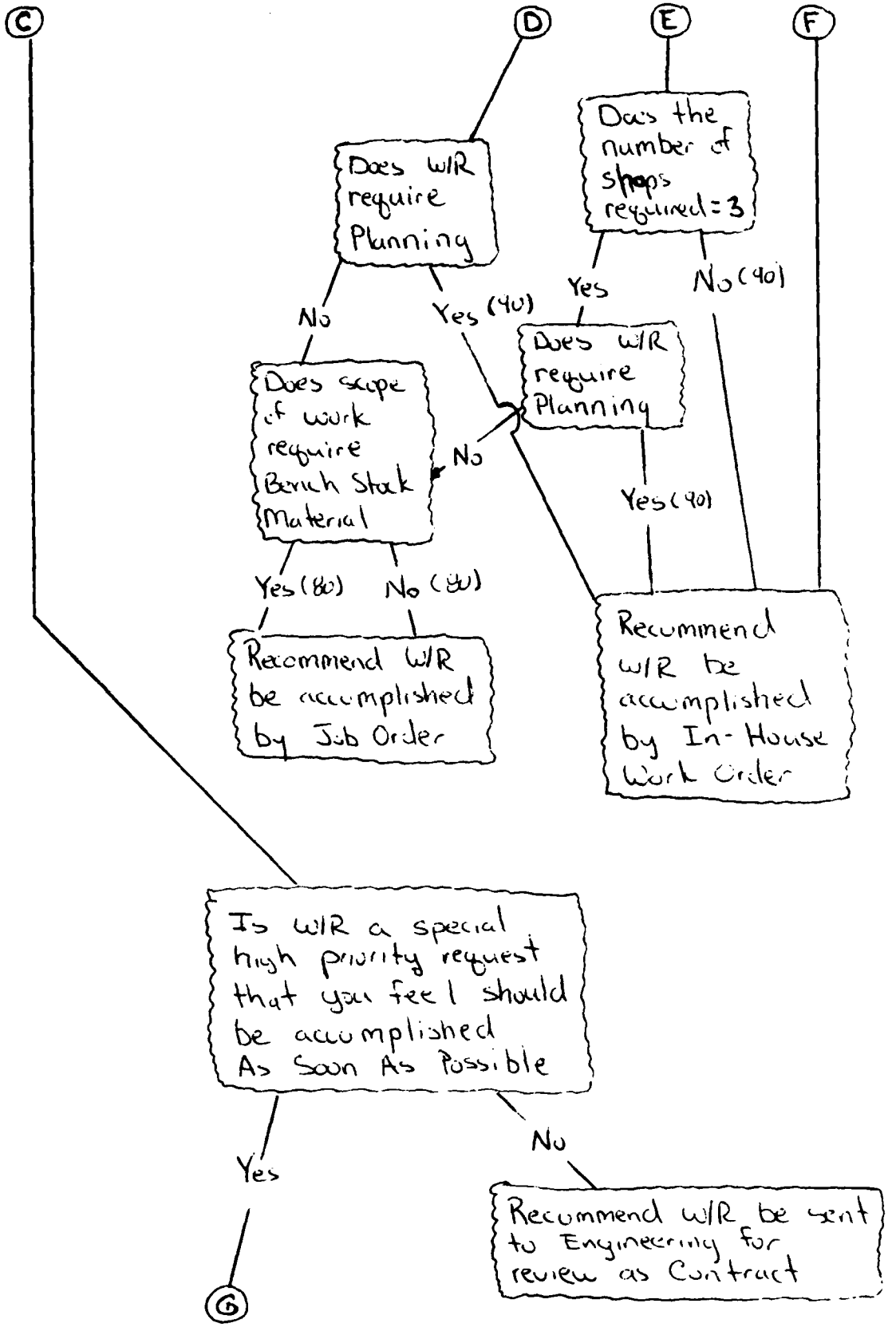
Capt Vroman, George AFB

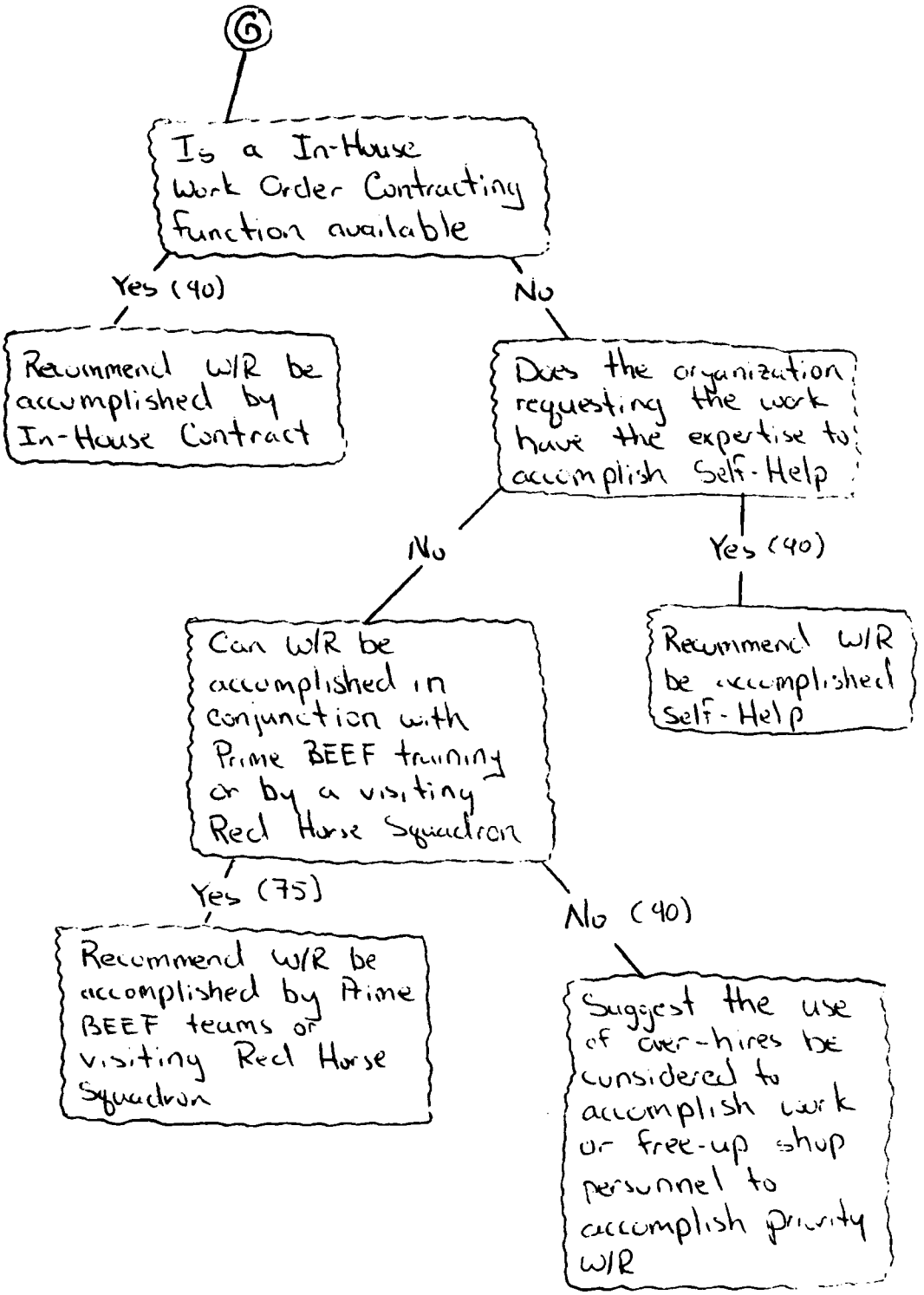
Capt Somers, Holloman AFB

Appendix E: Concept Map Representing Initial Knowledge Base




A
B
Are In-House resources (man-hours, funds, equipment, and expertise) available for work request ... Is it the type of work you would like to try In-House
Has AF Form 1391c been completed
No
Yes
Prepare AF Form 1391c
Are In-House resources available for W/R
No (80)
Yes (50)
Recommend W/R be accomplished by Contract
Recommend W/R be accomplished by In-House Work Order
Yes
If customer is requesting work be accomplished Self-Help
Then
Does the customer have the expertise
Yes
No
Recommend W/R be accomplished Self-Help
No
If work class is Maintenance and Repair
If work class is Minor Construction
Then
Then
Does the number of shops required = 1
Does scope of work require Cpertalization
No (75) (90)
Yes
No
Does W/R require Planning
Does the number of shops required = 2
Yes (75)
No
Recommend W/R be accomplished by Job Order
Yes
No
Yes
C
D
E
F


C
D
E
F
Does W/R require Planning
Does the number of shops required = 3
No
Yes (40)
Yes
No (40)
Does scope of work require Bench Stock Material
Does W/R require Planning
No
Yes (40)
Yes (80)
No (80)
Recommend W/R be accomplished by Job Order
Recommend W/R be accomplished by In-House Work Order
Is W/R a special high priority request that you feel should be accomplished As Soon As Possible
Yes
No
Recommend W/R be sent to Engineering for review as Contract
G


6
Is a In-House Work Order Contracting function available
Yes (90)
No
Recommend W/R be accomplished by In-House Contract
Does the organization requesting the work have the expertise to accomplish Self-Help
No
Yes (90)
Recommend W/R be accomplished Self-Help
Can W/R be accomplished in conjunction with Prime BEEF training or by a visiting Red Horse Squadron
Yes (75)
No (90)
Recommend W/R be accomplished by Prime BEEF teams or visiting Red Horse Squadron
Suggest the use of over-hires be considered to accomplish work or free-up shop personnel to accomplish priority W/R

Appendix F: Production Rules For Expert System

Rule #1 Source: Gaulin

IF:
Work request description is CE responsibility AND
A duplicate work request is not in the system AND
The scope of work is clear AND
Work request does not have proper coordination

THEN:
Return work request to customer for proper coordination (Confidence 100%)

Rule #2 Source: Gaulin

IF:
Work request description is CE responsibility AND
A duplicate work request is in the system

THEN:
Send work request back to the customer explaining status of old request (Confidence 100%)

Rule #3 Source: Gaulin

IF:
Work request description is CE responsibility AND
A duplicate work request is not in the system AND
The scope of work is not clear AND
The description of work is unique to one superintendent

THEN:
Send work request to the specific superintendent to review the work requested (Confidence 100%)

Rule #4 Source: Gaulin

IF:
Work request description is CE responsibility AND
A duplicate work request is not in the system AND
The scope of work is not clear AND
The description of work is not unique to one superintendent

THEN:
Send work request to Planning for 'Shot-Gun' estimate (Confidence 100%)

Rule #5 Source: Eide and AFR 85-2

IF:
Work request description is not CE responsibility AND
Work classification is Local Manufacturer

THEN:
Ensure Supply has accomplished DD Form 1348-1 and accomplish work by In-House work order only if specific shops involved do not have a back log or require training on work requested

Rule #6 Source: Gaulin

IF:
Work request description is not CE responsibility AND
The proper approval authority does not want it done

THEN:
Recommend work request be sent back to the customer disapproved (Confidence 100%)

Rule #6.7 Source: Mr Johnson

IF:
Work request description is CE responsibility OR

[The proper approval authority does want it done
AND
Work request description is not CE responsibility]
AND
Work request is classified as Work for Others

THEN:
Recommend work request be accomplished as a work order in order to collect for reimbursable work (Confidence 100%)

Rule #7 Source: Gaulin

IF:
Work request description is not CE responsibility
AND
The proper approval authority wants it done AND
The scope of work is clear AND
Work request does not have proper coordination

THEN:
Return work request to customer for proper coordination (Confidence 100%)

Rule #8 Source: Gaulin

IF:
Work request description is not CE responsibility
AND
The proper approval authority wants it done AND
The scope of work is not clear AND
The description of work is unique to one superintendent

THEN:
Send work request to specific superintendent to review work (Confidence 100%)

Rule #9 Source: Gaulin

IF:
Work request description is not CE responsibility
AND
The proper approval authority wants it done AND
The scope of work is not clear AND

The description of work is not unique to one superintendent

THEN:

Send work request to Planning for 'Shot-Gun' estimate (Confidence 100%)

Rule #10 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility AND
A duplicate work request is not in the system AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may impact the environment AND
Environmental Impact Statement (EIS) is not prepared

THEN:

Recommend work request be sent to Environmental Engineering to prepare EIS (Confidence 100%)

Rule #11 Source: Gaulin and AFR 85-2

IF:

Work request description is not CE responsibility AND
The proper approval authority wants it done AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may impact the environment AND
Environmental Impact Statement (EIS) is not prepared

THEN:

Recommend work request be sent to Environmental Engineering to prepare EIS (Confidence 100%)

Rule #12 Source: Gaulin

IF:

Work request description is CE responsibility AND
A duplicate work request is not in the system AND
The scope of work is clear AND

Work request has proper coordination AND
Scope of work may impact the environment AND
Environmental Impact Statement (EIS) is prepared

THEN:
Recommend work request be accomplished by contract and sent to Engineering for further review (Confidence 100%)

Rule #13 Source: Gaulin

IF:
Work request description is not CE responsibility AND
The proper approval authority wants it done AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may impact the environment AND
Environmental Impact Statement (EIS) is prepared

THEN:
Recommend work request be accomplished by contract and sent to Engineering for further review (Confidence 100%)

Rule #14 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility AND
A duplicate work request is not in the system AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
[The dollar estimate is above the Installation Commander's approval authority OR
MAJCOM specifically requires approval for this request] AND
AF Form 1391c is not complete

THEN:
Recommend work request be sent to engineering to prepare AF Form 1391c (Confidence 100%)

Rule #15 Source: Gaulin and AFR 85-2

IF:

Work request description is not CE responsibility
AND
The proper approval authority wants it done AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
[The dollar estimate is above the Installation
Commander's approval authority OR
MAJCOM specifically requires approval for this
request] AND
AF Form 1391c is not complete

THEN:

Recommend work request be sent to engineering to
prepare AF Form 1391c (Confidence 100%)

Rule #16 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
[The dollar estimate is above the Installation
Commander's approval authority OR
MAJCOM specifically requires approval for this
request] AND
AF Form 1391c is complete AND
In-House resources (man-hours, money, and/or
materials) exist

THEN:

Recommend work request be accomplished by In-House
work order (Confidence 80%)

Rule #17 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND

Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
[The dollar estimate is above the Installation Commander's approval authority OR
MAJCOM specifically requires approval for this request] AND
AF Form 1391c is complete AND
In-House resources (man-hours, money, and/or materials) do not exist

THEN:
Recommend work request be accomplished by Contract
(Confidence 80%)

Rule #18 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
The customer is requesting the work be accomplished self-help AND
Customer has the ability to do work self-help

THEN:
Recommend work request be accomplished self-help
(Confidence 100%)

Rule #19 Source: Gaulin, Eide, and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND

The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
The customer is requesting the work be accomplished self-help AND
Customer does not have the ability to do work self-help

THEN:

Recommend Planning and customer discuss exactly how much shop support or customer training is required (Confidence 75%)

Rule #20 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility] AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves only one shop AND
Work request does require detailed planning

THEN:

Recommend work request be accomplished by Job Order (Confidence 75%)

Rule #21 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility] AND

The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves two shops AND
Work request does require detailed planning

THEN:
Recommend work request be accomplished by In-House
work order (Confidence 90%)

Rule #22 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves three shops AND
Work request does require detailed planning

THEN:
Recommend work request be accomplished by In-House
work order (Confidence 90%)

Rule #23 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND

The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves more than three shops AND
Work request does require detailed planning

THEN:
Recommend work request be accomplished by In-House work order (Confidence 90%)

Rule #24 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility] AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves only one shop AND
Work request does not require detailed planning

THEN:
Recommend work request be accomplished by Job Order (Confidence 100%)

Rule #25 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility] AND

The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves only two shops AND
Work request does not require detailed planning AND
Scope of work requested involves bench-stock material

THEN:

Recommend work request be accomplished by Job Order (Confidence 80%)

Rule #26 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility] AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves three shops AND
Work request does not require detailed planning AND
Scope of work requested involves bench-stock material

THEN:

Recommend work request be accomplished by Job Order (Confidence 80%)

Rule #27 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR

[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves only two shops AND
Work request does not require detailed planning
AND
Scope of work requested does not require bench-
stock material

THEN:
Recommend work request be accomplished by Job
Order (Confidence 80%)

Rule #28 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) exist AND
Work classification is Maintenance and Repair AND
Scope of work involves three shops AND
Work request does not require detailed planning
AND
Scope of work requested does not require bench-
stock material

THEN:
Recommend work request be accomplished by Job
Order (Confidence 80%)

Rule #29 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR

[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) exist AND
Work classification is Minor Construction AND
Scope of work requires capitalization

THEN:

Recommend work request be accomplished by In-House work order (Confidence 100%)

Rule #30 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves only one shop AND
Work request does require detailed planning

THEN:

Recommend work request be accomplished by Job Order (Confidence 75%)

Rule #31 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND

Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves two shops AND
Work request does require detailed planning

THEN:
Recommend work request be accomplished by In-House work order (Confidence 90%)

Rule #32 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves three shops AND
Work request does require detailed planning

THEN:
Recommend work request be accomplished by In-House work order (Confidence 90%)

Rule #33 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND

Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves more than three shops AND
Work request does require detailed planning

THEN:
Recommend work request be accomplished by In-House work order (Confidence 90%)

Rule #34 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves only one shop AND
Work request does not require detailed planning

THEN:
Recommend work request be accomplished by Job Order (Confidence 100%)

Rule #35 Source: Gaulin and AFR 85-2

IF:
Work request description is CE responsibility OR
[The proper approval authority wants it done AND

Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves only two shops AND
Work request does not require detailed planning AND
Scope of work requested involves bench-stock material

THEN:

Recommend work request be accomplished by Job Order (Confidence 80%)

Rule #36 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves three shops AND
Work request does not require detailed planning AND
Scope of work requested involves bench-stock material

THEN:

Recommend work request be accomplished by Job Order (Confidence 80%)

Rule #37 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves only two shops AND
Work request does not require detailed planning AND
Scope of work requested does not require bench-stock material

THEN:

Recommend work request be accomplished by Job Order (Confidence 80%)

Rule #38 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) exist AND
Work classification is Minor Construction AND
Scope of work does not require capitalization AND
Scope of work involves three shops AND
Work request does not require detailed planning AND
Scope of work requested does not require bench-stock material

THEN:

Recommend work request be accomplished by Job Order (Confidence 80%)

Rule #39 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) do not exist AND
Work request is something YOU feel should not be done soon

THEN:

Recommend contracting option be exercised (Confidence 90%)

Rule #40 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) do not exist AND
Work request is something YOU feel should be done soon AND
In-House Work Order Contracting exists

THEN:

Recommend In-House Contracting option be exercised (Confidence 90%)

Rule #41 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) do not exist AND
Work request is something YOU feel should be done
soon AND
Customer has the expertise to accomplish work

THEN:

Recommend work request be accomplished Self-Help
(Confidence 90%)

Rule #42 Source: Gaulin, Eide, and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation
Commander's approval authority AND
In-House resources (man-hours, money, and/or
materials) do not exist AND
Work request is something YOU feel should be done
soon AND
Customer does not have the expertise to accomplish
work AND
Work can be accomplished in conjunction with Prime
BEEF training

THEN:

Recommend work request be reviewed by Prime BEEF office as a potential job for the next bivouac or exercise (Confidence 75%)

Rule #43 Source: Gaulin and AFR 85-2

IF:

Work request description is CE responsibility OR
[The proper approval authority wants it done AND
Work request description is not CE responsibility]
AND
The scope of work is clear AND
Work request has proper coordination AND
Scope of work may not impact the environment AND
The dollar estimate is below the Installation Commander's approval authority AND
In-House resources (man-hours, money, and/or materials) do not exist AND
Work request is something YOU feel should be done soon AND
Customer does not have the expertise to accomplish work AND
Work can not be accomplished in conjunction with Prime BEEF training

THEN:

Recommend over hires be brought on board to help accomplish work if funds are available (Confidence 90%)

Appendix G: VP-Expert Program

```
RUNTIME;
ENDOFF;

ACTIONS
COLOR = 5
     DISPLAY "Welcome to the 1st Work Request Recommendation
Expert System!!

     ...For explanations of specific Questions,
        press the '/' key and follow the menu
        before answering the question of interest...

     ...If you are not 100% sure of your choice, hit
        the 'HOME' key prior to hitting enter and the
        type your confidence factor  (0-100) associated
        with the answer... after typing the confidence
        factor, hit the enter key followed by pressing the
        'END' key.


Please press any key to begin the consultation.

COLOR = 14
     FIND Recommendation
     DISPLAY "Based on your answers concerning the Work
Request in question, the Expert System's recommendation is
to (*Recommendation)."";


RULE 1
IF   Description=Civil_Engineering AND
     Duplicate=No AND
     Scope=Clear AND
     Coordination=Not_Complete

THEN
     Recommendation=Return_To_Customer;


RULE 2
IF   Description=Civil_Engineering AND
     Duplicate=Yes

THEN
     Recommendation=Return_to_Cust
     BECAUSE "Duplicate work requests are not desired."";
```

```
RULE 3
IF   Description=Civil_Engineering AND
     Duplicate=No AND
     Scope=Unclear AND
     Super_Stat=Unique_to_one

THEN
     Recommendation=Send_to_Super
     BECAUSE 'That one superintendent will give you a better
understanding of the scope of work and if the work is
needed.';


RULE 4
IF   Description=Civil_Engineering AND
     Duplicate=No AND
     Scope=Unclear AND
     Super_Stat=Varied

THEN
     Recommendation=Send_to_Planning
     BECAUSE 'We are trying to determine if Planning needs
to review the particular work request before approval is
given.';


RULE 5
IF   Description=Civil_Engineering AND
     Work_Classification=Local_Manufacturer

THEN
     Recommendation=Do_1348_and_hold
     BECAUSE 'If the work classification is Local
Manufacturer, then supply is required to accomplish AF Form
1348-1 and you probably would want to hold the request and
send it to the shop of interest when they have time (e.g. no
Backlog).';


RULE 6
IF   Description=Others AND
     Approval_Auth=Boss_is_Indifferent

THEN
     Recommendation=Send_it_back
     BECAUSE 'Even though the work may not be civil
engineering's responsibility, the mission or our boss may
require us to do the work.  Don't always throw the
regulations out and look for reasons why we can't do work.';
```

```
RULE 6.5
IF   Description=Others AND
     Approval_Auth=Boss_says_do_IT

THEN
     Status=Hot
     BECAUSE 'Even though the work may not be civil
engineering's responsibility, the mission or our boss may
require us to do the work.  Don't always throw the
regulations out and look for reasons why we can't do work.';


RULE 6.7
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Work_Classification=Work_For_Others

THEN
     Recommendation=Appr_As_Work_Request
     BECAUSE 'Work for others is refundable and a AF Form
332 is required to bill the organization requesting the
work.';


RULE 7
IF   Status=Hot AND
     Scope=Clear AND
     Coordination=Not_Complete

THEN
     Recommendation=Return_for_Coord;


RULE 8
IF   Status=Hot AND
     Scope=Unclear AND
     Super_Stat=Unique_to_One

THEN
     Recommendation=Send_to_Super
     BECAUSE 'That one superintendent will give you a better
understanding of the scope of work and if the work is
needed.';


RULE 9
IF   Status=Hot AND
     Scope=Unclear AND
     Super_Stat=Varied

THEN
     Recommendation=Send_to_Planning
```

```
     BECAUSE 'We are trying to determine if Planning needs
to review the particular work request before approval is
given.';


RULE 10
IF   Description=Civil_Engineering AND
     Duplicate=No AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=Yes AND
     EIS=Not_Complete

THEN
     Recommendation=Send_to_DEEV
     BECAUSE 'We are attempting to determine if the scope of
work effects the environment and the EIS is not complete,
then DEEV should review the particular request to determine
if an EIS is required.';


RULE 11
IF   Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_prob=Yes AND
     EIS=Not_Complete

THEN
     Recommendation=Send_to_DEEV
     BECAUSE 'We are attempting to determine if the scope of
work effects the environment and the EIS is not complete,
then DEEV should review the particular request to determine
if an EIS is required.';


RULE 12
IF   Description=Civil_Engineering AND
     Duplicate=No AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_prob=Yes AND
     EIS=Complete

THEN
     Recommendation=Approve_as_contract
     BECAUSE 'We are attempting to determine if the scope of
work effects the environment and the EIS is complete, then
DEEV should review the particular request as a potential
contract.';
```

```
RULE 13
IF    Status=Hot AND
      Scope=Clear AND
      Coordination=Complete AND
      Environment_Prob=Yes AND
      EIS=Complete

THEN
      Recommendation=Approve_as_contract
      BECAUSE 'We are attempting to determine if the scope of
work effects the environment and the EIS is complete, then
DEEV should review the particular request as a potential
contract.';


RULE 14
IF    Description=Civil_Engineering AND
      Duplicate=No AND
      Scope=Clear AND
      Coordination=Complete AND
      Environment_Prob=No AND
      IC_Approval=Above OR
      MAJCOM_Spec=Requires_Approval AND
      AF1391=Not_Complete

THEN
      Recommendation=Send_to_DEEV
      BECAUSE 'We are attempting to determine that if the
cost estimate of the work request is above the Installation
Commander's approval authority or MAJCOM specifically
requests approval on this request and AF Form 1391c is not
complete, then DEEV is required to complete AF Form 1391c.';


RULE 15
IF    Status=Hot AND
      Scope=Clear AND
      Coordination=Complete AND
      Environment_Prob=No AND
      IC_Approval=Above OR
      MAJCOM_Spec=Requires_Approval AND
      AF1391=Not_Complete

THEN
      Recommendation=Send_to_DEEV
      BECAUSE 'We are attempting to determine that if the
cost estimate of the work request is above the Installation
Commander's approval authority or MAJCOM specifically
requests approval on this request and AF Form 1391c is not
complete, then DEEV is required to complete AF Form 1391c.';
```

```
RULE 16
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=No AND
     IC_Approval=Above OR
     MAJCOM_Spec=Requires_Approval AND
     AF1391=It_is_Complete AND
     Resources=Exist

THEN
     Recommendation=Appr_as_Work_Order CNF 80;


RULE 17
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=No AND
     IC_Approval=Above OR
     MAJCOM_Spec=Requires_Approval AND
     AF1391=It_is_Complete AND
     Resources=Not_Available

THEN
     Recommendation=Approve_as_Contract CNF 80;


RULE 18
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=No AND
     IC_Approval=Below AND
     Resources=Exist AND
     Self_Help_Request=Yes AND
     Expertise=Yes

THEN
     Recommendation=Approve_as_Self_Help;


RULE 19
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=No AND
     IC_Approval=Below AND
```

```
     Resources=Exist AND
     Self_Help_Request=Yes AND
     Expertise=No

THEN
     Recommendation=Approve_as_Self_Help CNF 75;


RULE 20
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=No AND
     IC_Approval=Below AND
     Resources=Exist

THEN
     In_House=Yes;


RULE 20.5
IF   In_House=Yes AND
     Work_Classification=Maint_And_Repair AND
     Shop_Num=One AND
     Det_Plan=Required

THEN
     Recommendation=Approve_as_Job_Order CNF 75;


RULE 21
IF   In_House=Yes AND
     Work_Classification=Maint_And_Repair AND
     Shop_Num=Two AND
     Det_Plan=Required

THEN
     Recommendation=Appr_as_Work_Order CNF 90;


RULE 22
IF   In_House=Yes AND
     Work_Classification=Maint_And_Repair AND
     Shop_Num=Three AND
     Det_Plan=Required

THEN
     Recommendation=Appr_as_Work_Order CNF 90;
```

```
RULE 23
IF    In_House=Yes AND
      Work_Classification=Maint_And_Repair AND
      Shop_Num=More AND
      Det_Plan=Required

THEN
      Recommendation=Appr_as_Work_Order CNF 90;


RULE 24
IF    In_House=Yes AND
      Work_Classification=Maint_And_Repair AND
      Shop_Num=One AND
      Det_Plan=Not_Required

THEN
      Recommendation=Approve_as_Job_Order;


RULE 25
IF    In_House=Yes AND
      Work_Classification=Maint_And_Repair AND
      Shop_Num=Two AND
      Det_Plan=Not_Required AND
      Bench_Stock=Yes

THEN
      Recommendation=Approve_as_Job_Order CNF 80;


RULE 26
IF    In_House=Yes AND
      Work_Classification=Maint_And_Repair AND
      Shop_Num=Three AND
      Det_Plan=Not_Required AND
      Bench_Stock=Yes

THEN
      Recommendation=Approve_as_Job_Order CNF 80;


RULE 27
IF    In_House=Yes AND
      Work_Classification=Maint_And_Repair AND
      Shop_Num=Two AND
      Det_Plan=Not_Required AND
      Bench_Stock=No

THEN
      Recommendation=Approve_as_Job_Order CNF 80;
```

```
RULE 28
IF    In_House=Yes AND
      Work_Classification=Maint_And_Repair AND
      Shop_Num=Three AND
      Det_Plan=Not_Required AND
      Bench_Stock=No

THEN
      Recommendation=Approve_as_Job_Order CNF 80;


RULE 29
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=Yes

THEN
      Recommendation=Appr_as_Work_Order;


RULE 30
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=One AND
      Det_Plan=Required

THEN
      Recommendation=Approve_as_Job_Order CNF 75;


RULE 31
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=Two AND
      Det_Plan=Required

THEN
      Recommendation=Appr_as_Work_Order CNF 90;


RULE 32
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=Three AND
      Det_Plan=Required

THEN
      Recommendation=Appr_as_Work_Order CNF 90;
```

```
RULE 33
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=More AND
      Det_Plan=Required

THEN
      Recommendation=Appr_as_Work_Order CNF 90;


RULE 34
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=One AND
      Det_Plan=Not_Required

THEN
      Recommendation=Approve_as_Job_Order;


RULE 35
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=Two AND
      Det_Plan=Not_Required AND
      Bench_Stock=Yes

THEN
      Recommendation=Approve_as_Job_Order CNF 80;


RULE 36
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
      Shop_Num=Three AND
      Det_Plan=Not_Required AND
      Bench_Stock=Yes

THEN
      Recommendation=Approve_as_Job_Order CNF 80;


RULE 37
IF    In_House=Yes AND
      Work_Classification=Minor_Construction AND
      Capitalization=No AND
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     Shop_Num=Two AND
     Det_Plan=Not_Required AND
     Bench_Stock=No

THEN
     Recommendation=Approve_as_Job_Order CNF 80;


RULE 38
IF   In_House=Yes AND
     Work_Classification=Minor_Construction AND
     Capitalization=No AND
     Shop_Num=Three AND
     Det_Plan=Not_Required AND
     Bench_Stock=No

THEN
     Recommendation=Approve_as_Job_Order CNF 80;


RULE 38.5
IF   Description=Civil_Engineering OR
     Status=Hot AND
     Scope=Clear AND
     Coordination=Complete AND
     Environment_Prob=No AND
     IC_Approval=Below OR
     MAJCOM_Spec=Requires_Approval AND
     Resources=Not_Available

THEN
     In_House=No;


RULE 39
IF   In_House=No AND
     Priority=No

THEN
     Recommendation=Approve_as_Contract;


RULE 40
IF   In_House=No AND
     Priority=Yes AND
     In_House_Contract=Exists

THEN
     Recommendation=Use_SABER_or_like CNF 90
     BECAUSE 'We are attempting to determine if the work
request is a priority request because of Safety, Mission, or
```

```
some other reason.  If it is a priority, then it should be
accomplished as soon as possible.

                                   Even though resources appear
not to be available, the Chief of Operations usually has
other options he can take to accomplish a priority work
request.  This question and rule look at one of those
options.';


RULE 41
IF    In_House=No AND
      Priority=Yes AND
      Expertise=Yes

THEN
      Recommendation=Approve_Self_Help CNF 90
      BECAUSE 'We are attempting to determine if the work
request is a priority request because of Safety, Mission, or
some other reason.  If it is a priority, then it should be
accomplished as soon as possible.

                                   Even though resources appear
not to be available, the Chief of Operations usually has
other options he can take to accomplish a priority work
request.  This question and rule look at one of those
options.';


RULE 42
IF    In_House=No AND
      Priority=Yes AND
      Expertise=No AND
      Prime_BEEF=Yes

THEN
      Recommendation=Use_Prime_BEEF_teams CNF 75
      BECAUSE 'We are attempting to determine if the work
request is a priority request because of Safety, Mission, or
some other reason.  If it is a priority, then it should be
accomplished as soon as possible.

                                   Even though resources appear
not to be available, the Chief of Operations usually has
other options he can take to accomplish a priority work
request.  This question and rule look at one of those
options.';


RULE 43
IF    In_House=No AND
      Priority=Yes AND
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```
     Expertise=No AND
     Prime_BEEF=No

THEN
     Recommendation=Use_Over_Hires CNF 90
     BECAUSE "We are attempting to determine if the work
request is a priority request because of Safety, Mission, or
some other reason.  If it is a priority, then it should be
accomplished as soon as possible.

                                   Even though resources appear
not to be available, the Chief of Operations usually has
other options he can take to accomplish a priority work
request.  This question and rule look at one of those
options.";



ASK Description : "According to the work location and
description, who has responsibility for accomplishing the
work?";

CHOICES Description : Civil_Engineering, Others;


ASK Duplicate : "Is the work request of interest a duplicate
of an existing, active request?";

CHOICES Duplicate : Yes, No;


ASK Scope : "What is the scope of work?  Is it clear or
unclear... in other words do you have a feel for
the amount of man-hours and funding required?";

CHOICES Scope : Clear, Unclear;


ASK Coordination : "What is the status of coordination on
the work request of interest?  Don't forget the Fire
Department.";

CHOICES Coordination : Complete, Not_Complete;


ASK Super_Stat : "Is the description of work unique to one
superintendent's area or is it varied between
Superintendents?";

CHOICES Super_Stat : Unique_to_one, Varied:
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ASK Work_Classification : 'What work classification does the
work request fall into?';

CHOICES Work_Classification : Minor_Construction,
Maint_and_Repair, Local_Manufacturer, Work_For_Others;


ASK Approval_Auth : 'Even though the work request is not CEs
responsibility, does the proper approval authority within CE
want us to do the work?';

CHOICES Approval_Auth : Boss_says_do_IT,
Boss_is_Indifferent;


ASK Environment_Prob : 'Does the scope of work appear that
it will effect the environment?';

CHOICES Environment_Prob : Yes, No;


ASK EIS : 'Has an Environmental Impact Statement, AF Form
813, been completed?';

CHOICES EIS : Complete, Not_Complete;


ASK IC_Approval : 'Based on preliminary estimates, do you
feel the dollar estimate of this work request is ABOVE or
BELOW the Installation Commander's Approval Authority?';

CHOICES IC_Approval : Above, Below;


ASK MAJCOM_Spec : 'Does the MAJCOM specifically require
approval of this work request or are they indifferent?';

CHOICES MAJCOM_Spec : Requires_Approval, Indifferent;


ASK AF1391 : 'Has DEE accomplished AF Form 1391c?';

CHOICES AF1391 : It_is_Complete, Not_Complete;


ASK Resources : 'Do you believe that this type of work can
be accomplished by the shops and....

Do you feel that In-House resources (Man-Hours,
Money, and/or Materials) exist to accomplish the work
request in question?';
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CHOICES Resources : Exist, Not_Available;

ASK Self_Help_Request : 'Is the customer requesting the work
be accomplished self-help?';

CHOICES Self_Help_Request : Yes, No;

ASK Expertise : 'In your opinion, or your superintendents,
does the customer have the expertise and ability to
accomplish the work?';

CHOICES Expertise : Yes, No;

ASK Shop_Num : 'How many shops will be required to
accomplish the work in question?';

CHOICES Shop_Num : One, Two, Three, More;

ASK Det_Plan : 'Does the work request require detailed
planning?';

CHOICES Det_Plan : Required, Not_Required;

ASK Bench_Stock : 'Is the material required to accomplish
the work within Bench Stock?';

CHOICES Bench_Stock : Yes, No;

ASK Capitalization : 'Does the scope of work require
capitalization?';

CHOICES Capitalization : Yes, No;

ASK Priority : 'Even though resources do not exist within
Operations to accomplish the work, do you feel the work
requested has high priority and should be done as soon as
possible?';

CHOICES Priority : Yes, No;

ASK In_House_Contract : 'Does a In-House work order
contracting function like SABER exist?';
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CHOICES In_House_Contract : Exists, Not_Available;

ASK Prime_BEEF : 'Can the work request be accomplished in
conjunction with Prime BEEF training?';

CHOICES Prime_BEEF : Yes, No;
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ABSTRACT

Expert systems are being developed in several industries throughout the world. The critical element in developing these systems is gathering the knowledge. The purpose of this study was to establish procedures for gathering this knowledge in Air Force Civil Engineering. As a test of the procedures, an expert system was created to solve two common semistructured decisions in civil engineering operations. These two decisions involved approving or disapproving a work request, and then determining the appropriate method of accomplishing approved work.

The primary emphasis of the study was on developing and exercising a specific methodology for extracting the knowledge. Several journals and periodicals were reviewed to determine how a knowledge base is developed.

The knowledge base was automated using the expert shell VP-Expert by Paperback Software. The knowledge acquisition steps used in this research and the automated knowledge base are launching platforms for future research involving expert systems in Air Force Civil Engineering.